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Biomass availability in Sweden for use in blast furnaces

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Abstract

Based on the type of BF operated in Sweden, the pulverized coal (PC) has primarily been considered replaceable. If replacing the PC, a reduction of 1.25 Mton CO₂ annually is possible, which would require approximately 4 TWh charcoal (0.46 Mton) or 7.14 TWh of dry raw biomass. This amount of biomass is substantial and availability is the main concern discussed in this paper. Uncertainty of the future biomass supply makes predictions beyond 2030 difficult. However, the predictions used in this work indicate that there is an unused potential, which could cover the need of all PCI in Sweden. Other aspects could potentially limit the proportion of PCI replaced by biomass, which should be further investigated.

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Biomass, Charcoal, Coke, Coal, Blast furnace

Introduction

This study investigates the potential amount of available biomass in Sweden, for CO₂ reduction, in a form useful for the blast furnaces (BF) given in Table 1. 2008 was used for reference as it was an uneventful year with high production. The available conversion technologies with corresponding products are shown in Figure 1 (a). Three options for replacing the coal and coke have been identified, illustrated in Figure 1 (b). This study do not analyze the cost of reducing CO₂ emissions by this method, in fact the market is not perfect for such large purchases of biomass, a further economic modelling effort is required to predict costs and the impact on the market.

Table 1. Blast furnaces in Sweden (2014) [1], with estimated numbers for coal and coke consumption (2008) [2]

BF	Location (designation)	Coal/coke rate, kg/tHM (2014)	Working volume, m ³	Capacity, MtHM/year	Production, MtHM (2008)	Consumption, Mton (2008)	
						Coal	Coke
1	Luleå (M3)	135/320	2540	2.55	2.24 (1)	0.31 (1)	0.73 (1)
2	Oxelösund (M2)	110/370	1100	0.80	1.33 (2+3)	0.15 (2+3)	0.50 (2+3)
3	Oxelösund (M4)	95/365	1339	1.10			

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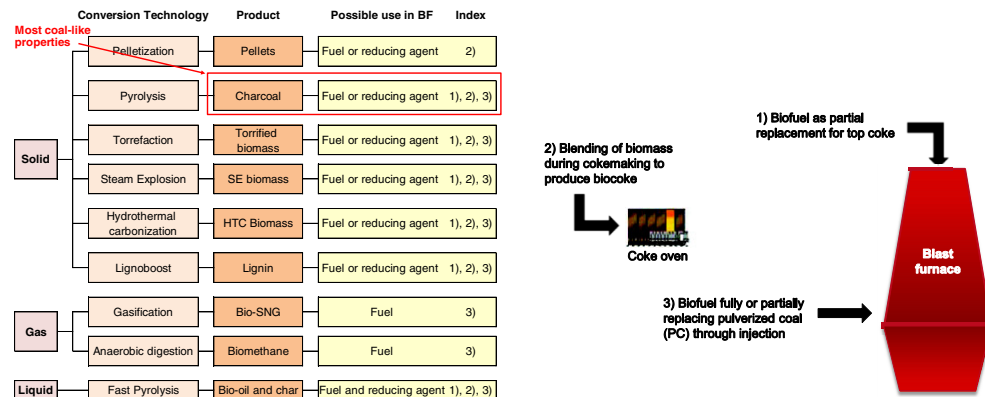


Fig 1. (a) Available biomass conversion technologies in Sweden; (b) The blast furnace with different ways of implementing biomass

Table 2. Details of available solid conversion technologies shown in Fig. 1 (a), for biomass in Sweden [2]

Parameter, unit	Solid conversion process					
	Pelletization	Pyrolysis	Torrefaction	Steam Explosion	HTC	LignoBoost
Temp, °C	70	400-500	200-300	160-260	180-220	70
Pressure, MPa	High	-	-	0.7-5	2.3-2.5	High
Product	Pellets	Charcoal	Torrefied biomass	SE biomass	HTC biomass	Pellets
Yield, wt%	~100	35	70	70	70	~100
Yield, energy%	~100	56	90	79	80	~100
Source	Several	Skogens kol	Torkapparater	SEKAB	KTH	Several
Production	2.3 Mton/y	6000 ton/y	1 ton/h	-	-	2.3 Mton/y
Status	Industrial use	Small scale	Pilot	Pilot	Lab	Commercial
Price, €/MWh	33	55	39.5-67.7	-	29.2	33

In this work we have based the scenario on using charcoal as the method to decrease CO₂ emissions. Table 3 represents a literature review on replacing coal and coke, with conclusions, recommendations and possible reductions in CO₂ emissions. The criteria on biomass properties is less demanding for replacement of coal for PCI, as a result this option is mainly considered in this paper.

Considering the hot metal production in Sweden which amounted to 3.56 Mton in 2008, as shown in Table 1, the used amount of pulverized coal was 0.457 Mton (or 4 TWh). Replacement is presumed to require the same amount of energy, 4 TWh charcoal (or 0.456 Mton). By assuming an energy and mass output yield yield of 56% and 35% respectively for slow pyrolysis (see Table 2), 7.14 TWh or 1.3 Mton of dry raw biomass will be needed. This would result in a reduction of CO₂ emissions by 1.46-1.82 Mton CO₂ by using the estimate in Table 3 (6.6 Mton CO₂ in total was emitted by the Swedish steel industry in 2008). The availability of such large amounts of raw biomass is the main concern discussed in this paper.

Table 3. Selected previous work on coke and coal replacement with biomass

Use in BF	Details of previous studies			
	[Ref.] Org.	General conclusion	Recommendation	CO ₂ reduction potential [3]
1. Replace coke in large blast furnace	[3] BlueScope, CSIRO and OneSteel [4] CSIRO	- Reduced coke rate	- Replace 50-100 wt% nut coke - Max 20% replacement of lump coke	- 0.08-0.16 tCO ₂ /tHM (50-100 % replacement of 45 kg nut coke/tHM)
2. Biofuel blending in coke making	[5] Canmet Energy	- Decreased strength - Increased reactivity	- 5-10 wt% blend with charcoal Blend coarse charcoal (>10mm)	- 0.02-0.11 tCO ₂ /tHM (2-10% coal blend, with coke used at 300-350 kg/tHM)
3. Replace PCI in large blast furnace	[6] RWTH and CENIM [7] LASID and RWTH	- Higher combustion efficiency or burn out - Combusts readily with better flame stability	- 100 % replacement possible in large blast furnaces - Coal-charcoal blend is also possible, lower coke reactivity due to interaction	- 0.41-0.51 tCO ₂ /tHM (100% replacement of PCI at 150-200kg coal/tHM)

Biomass availability

To evaluate the biomass availability for use in Blast furnaces, a long term view is appropriate. In general, the industrial interest for biomass is considerable and the availability is an actively investigated issue in Sweden. Table 4 shows a summary of supply-potential studies in Sweden [10]. Table 5 shows a broad impact assessment [11] of regulations on biomass-use divided into different sectors, which assumes the iron and steel industry continue using fossil fuels.

Table 4. Estimated supply potential of biomass, adapted from Wetterlund et al. [10]

Biomass potential		Interval (number of studies), TWh/year				
		2000	2010	2020	2030	2040
Supply	Primary forest	16-113.5 (23)	25.8-111.0 (14)	16.0-126.0 (16)	16.0-71.2 (7)	
	Secondary residue	12-44 (13)	20-59.6 (6)	16.8-63.7 (9)	40.0-68.1 (2)	
	Stump	0.3-8.0 (5)	10.0-57.5 (4)	10.0 (1)		
	Total	80-159.6 (3)	111.0-173.8 (3)	107.0-181.7 (7)	143-195.2 (2)	132 (1)

Table 5. Estimated use of biomass, excluding Peat and Waste, adapted from Andersson et al [11]

Biomass potential		Estimated use based on regulation (Main scenario-High economic development), TWh/year				
		2007	2020	2030	2040	2050
Use	Industry	55.0-55.0	58.8-61.8	63.0-69.9		
	Transportation	3.5-3.5	6.2-6.2	6.7-6.7		
	Residential and service	13.9-13.9	15.7-15.7	16.0-16.0		
	Electricity		17-16.1	18.5-16.8		
	Heating	20.5	27.9-20.5	29.1-26.9		
	Total	102.5-102.5	124.9-127.4	133.9-138.5		

Fig 2 shows the present day plants of added-value uses of biomass. Pelletization plants often serves as collection points for sawmill and forest residue, where a market of homeowners exist for domestic use of pellets. When the residue is not pelletized, it is directly used in CHP boilers. Sawmills, Pulp and paper mills are another high added value use in Fig 2. Included in the figure is also predictions of supply (average of intervals in Table 4) and use (both scenarios in Table 5).

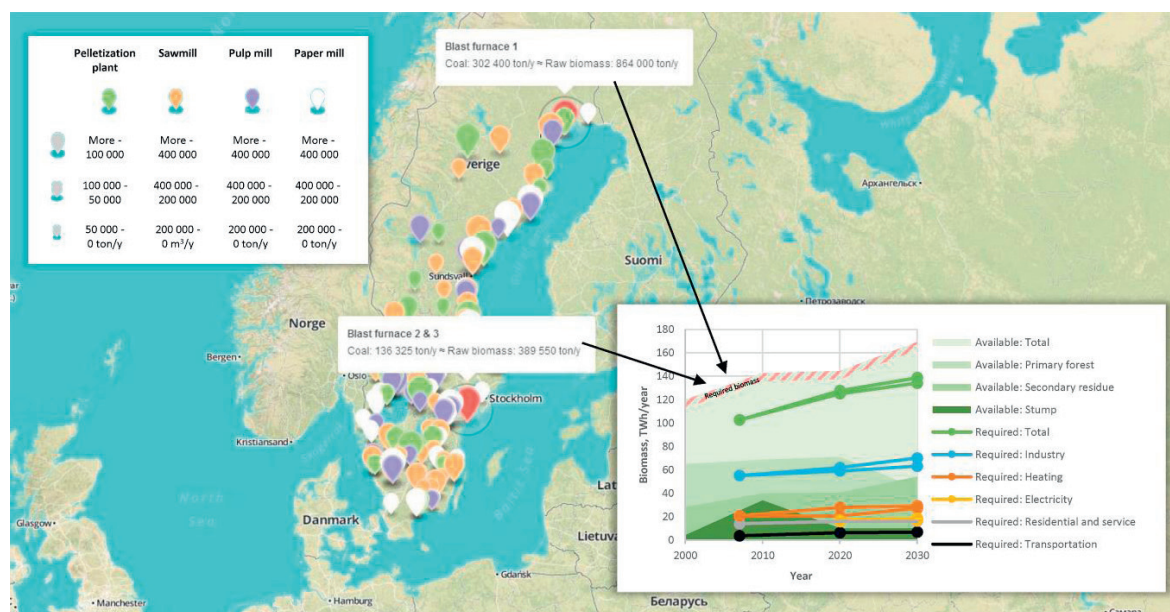


Fig 2. The blast furnaces in Sweden and other biomass users, with the required amount shown alongside predictions of supply [10] and use [11]

Conclusion

The uncertainty and hence the lack of predictions, makes it difficult to evaluate the biomass potential beyond 2030. Still this timeframe is not very far-reaching since the introduction of biomass in the blast furnaces will take time. There is potential for increased use of biomass, predictions indicate that in the mid-long term view as much as would be needed to replace PCI is available. The amount of residue not harvested today (such as stump, branches and tree-tops) is substantial, mainly remaining in north part of Sweden [12].

PCI could gradually be replaced, though sustainability of the harvesting of additional biomass should be ensured. Other aspects could potentially limit the proportion of PCI replaced by biomass, such as prohibitive costs, operating conditions and tolerable limits of contaminants in the crude steel. These other aspects should be further investigated.

Additionally, the available biomass is subject to competition. Other industries such as chemical, biofuel, and power industry are all interested in using more biomass. The development in each industry, which is also a matter of uncertainty, will affect the economic feasibility of using biomass in the steel industry.

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Biography

Pelle Mellin is a PhD student at KTH, in Sweden. His thesis work focuses on fast pyrolysis but he also works to bring about more biofuels into the steel industry. He holds a chair in board for Energy and Furnace Technology research, in the steel producers' association Jernkontoret, and has participated in several industrial projects.